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Knowledge of Doses from Radiumtherapy for Skin Hemangioma in Childhood

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Abstract

Before 1974 about 5000 children were irradiated at the *Institut Gustave-Roussy* for a skin hemangioma of whom 20% were treated with radium applicators. To evaluate the absorbed doses to these patients at any site, we have developed a software program wh)ch permits simulation of the actual patient and treatment conditions.
Part of this software is devoted to constructing an Individual Computerised Tomographic Anatomy (ICTA) based on real human transverse slices and auxological tables. From the generated phantom, 160 anatomical sites of epidemiological interest are defined and localised according to a Cartesian co-ordinate system.
The gamma doses at all sites from Ra-226 applicators are calculated by an algorithm which permits separation of the radiation paths in air, tissue, and lungs. It includes a correction for attenuation and scatter in infinite and semi-infinite mediums. To evaluate the factor $\varphi(r)$ for these corrections at any distance or position from the applicator, we have modelled the results from several Monte Carlo simulations.
In the range of 1 to 10 cm, the $\varphi(r)$ values obtained from our model showed good agreement with those obtained by published methods. For several cases, the absorbed doses at points in water and patients from radium applicators estimated by this software, were compared to those measured and estimated at the Karolinska Hospital. The results showed good agreement.

Introduction

Earlier studies to monitor the long-term radiogenetic risk after radiumtherapy for skin hemangioma in childhood confirmed a high risk [1-4]. In these studies, the dose estimation from radiumtherapy was based on standardised phantoms and treatments. To increase consideration of the strong graduation of the dose in the vicinity of the radioactive source, we initiated development of a more precise program for dose estimation in epidemiological studies. Initially, the program is used to evaluate radiation doses to a cohort of about 5000 children irradiated at the *Institut Gustave-Roussy* (IGR) for a skin hemangioma before 1974.
In this paper we describe briefly the anthropomorphic phantom established by this software, and the approach we have used to evaluate the effective transmission factor, and to calculate absorbed doses to various sites of patients.

Phantom

The first part of the program is devoted to constructing an Individual Computerised Ttomographic Anatomy (ICTA) based on real human transverse slices [5]. These slices were combined to construct a 3-D phantom. The phantom is segmented into 5 sections defined by x (left-right width), y (distance up-down), and z (post-ant thickness). In co-operation with paediatricians, we have defined and localised 160 anatomical sites of epidemiological interest.

When the information about a patient is introduced, the program calls auxological tables to select the reference parameters (mediastinal diameter, head width and thickness, bi-acromial and bi-iliac widths, and the distance from the base of the heel to the: chin, breast, gonad, and knee) corresponding to the sex and the age of the patient at the time of treatment, using the method described in [6]. The 5 sections of ICTA are thus adapted and the anatomical sites are relocalised. Figure 1 shows the frontal projection of ICTA phantom adapted to: 1, 12, and 24 month female children constructed by this software.

Applicator model

In the second part of the software, the radioactive applicators (type, geometry, and dimensions) are modelled. Precise 3-D positioning of the applicator (needles, tubes, flat sheets) and the shape of the treated region are considered. Once the phantom is adapted to the patient, the applicators are positioned according to available information, i.e. drawing, photograph, etc.. This information is saved independently of the dose calculation module, allowing for further extensions and improvements in dose calculation procedures.

Dose calculation

The gamma doses from radium applicators are calculated by an algorithm which forms the third. part of the software. The well known quantisation approach described in [7], is adopted. The active volume is divided into small elements, equal in size. The number of the elements depends on the source length (or surface area for radium plaques), and the distance source-point of interest, such that each element could be considered as a point source. The absorbed dose at any point is calculated from the widely used equation recommended by CFMRI* [8], which is based on the ICRU recommendations [9]. In this equation, the correction for attenuation and scattering in the medium is performed using the effective transmission factor $\varphi(r)$. To evaluate this factor, we have modelled the results of several Monte Carlo simulations using the EGS4 code system.

Results

In figure 2, we represent the variation of $\varphi(r)$ with distance (r) from the source. In the range of 1 to 10 cm, the $\varphi(r)$ values obtained by this model showed good agreement with those calculated by Meisberger [10]. For further distances our model extrapolates exponentially, permitting the continuity of the variation, as was suggested by an other author [11]. For the superficial sites, a correction is introduced to take into account the semi-infinite nature (lack of scattered radiation). Consideration of this correction is particularly important in our study as the radium applicators were applied on the skin surface. The sites located near the skin surface and on the same side of the treated region (e.g. breast when the treated region is the anterior abdominal region), receive lower doses as compared to points located at the same distance from the source and situated inside the body (e.g. heart). This algorithm estimates the photon path length separately, in air, tissue, and lung, which influence the attenuation and consequently the absorbed dose.
The absorbed doses at several sites within the patients and in water, estimated by this software, showed good agreement with those estimated and measured at Karolinska Hospital.

Discussion

The ability of our software to adapt ICTA to each patient allows for a precise estimate of (r).This factor is of major influence in estimation of the absorbed dose at any site. Evaluation of $\varphi(r)$ at any distance and at any position with a single model, not only simplifies the individual dosimetry, but

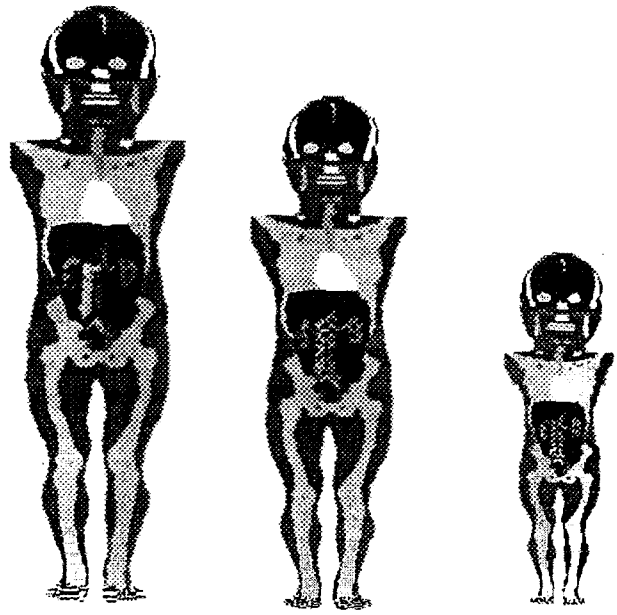

Figure 1. Frontal projection of ICTA phantom adapted to: 24, 12, and 1 month female children.

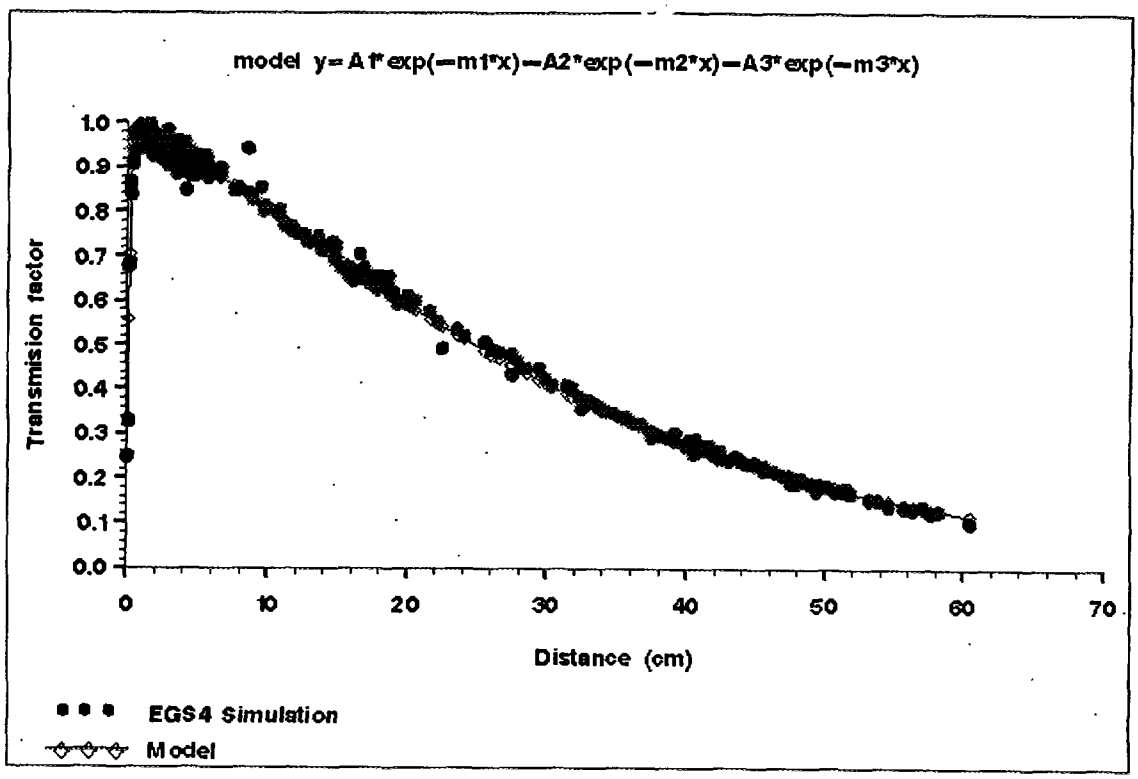

Figure 2. The transmission factor φ(r) as a function of distance, based on Monte Carlo simulations using the EGS4 code.

also allows for accurate estimation of the absorbed doses at points very close to the source (< 1 cm) and at distances larger than 10 cm, limits of other available models. Moreover the software can be easily handled, not only to input the information required for retrospective dose estimation (sex, age at the time of treatment, characteristics of the applicator, time of treatment) but also to localise the applicators correctly according to the drawings, photographs or any available information in the treatment records. This software can be easily adapted for dose calculations for any other radioactive source applied on the skin surface, or within the body.

Finally, our approach is a useful tool for individual dose estimation, particularly when large groups of patients are analysed. It is also useful when knowledge of the absorbed doses to numerous sites is required. The database constructed by our model could lead to evaluate dose-response relationship, and can help to improve knowledge of low dose-effects for the radiation protection purposes.

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